Enhancing Digital Competence by Exploring IoT Development in Digital Fabrication Laboratories for Digital Transformation

Dunja Ravnikar[1], Tomaž Berlec[1], Luís Rocha[2], Humberto Teixeira[2], Marco Braga[3], Marco Galanti[3], Maria Rodríguez Malmierca[4], Abraham Felpeto Guerrero[4], Reyan Korel Erben[5], Robert Hellbach[5], Edita de Lorenzo Rodríguez[6], Ana Estévez González[6]

[1]*Faculty of Mechanical Engineering, University of Ljubljana, Askerceva 6, 1000 Ljubljana, Slovenia*
[2]*Centro de Apoio Tecnologico a Industria Metalomecanic a Associacao, R. dos Plátanos 197, 4100-414 Porto, Potrugal*
[3]*Trasferimento Tecnologico e Innovazione Scarl, Piazza delle Istituzioni 34/a 31100 Treviso, Italy*
[4]*Fundacion Publica Gallega Centro Tecnologico de Supercomputa cion de Galicia, Edificio Cesga s/n, Avenida de Vigo, 15705 Santiago de Compostela, A Coruña, Spain*
[5]*Bremer Institut fuer Produktion und Logistik Hmbh. Hochschulring 20, 28359 Bremen, Germany*
[6]*Universidad de Vigo, Circunvalación ao Campus Universitario, 36310 Vigo, Pontevedra, Spain*

Email: dunja.ravnikar@fs.uni-lj.si, tomaz.berlec@fs.uni-lj.si, luis.rocha@catim.pt, humberto.teixeira@catim.pt, marco.braga@t2i.it, marco.galanti@t2i.it, mjrm@cesga.es, abraham.felpeto.guerrero@cesga.gal, erb@biba.uni-bremen.de, hel@biba.uni-bremen.de, edita.delorenzo@uvigo.gal, ana.estevez.gonzalez@uvigo.gal

Abstract. *This paper discusses the importance of addressing digital transformation by developing digital readiness, resilience, and capacity in higher education sectors, particularly focusing on enhancing STEM/STEAM education and increasing women's participation in STEM fields. It highlights the impact of the "Fourth Industrial Revolution" on manufacturing and engineering by integrating computer science advancements such as IoT, cloud computing, virtual reality, big data, and artificial intelligence. It emphasizes the need for training programs tailored to IoT technologies to prepare individuals for the changing industry landscape and the rise of intelligent machines in various sectors. In Erasmus+ project named FabLabs this issue will be addressed with a goal of developing learning materials, teaching strategies, and curriculum for IoT-related technologies. By adopting a learner-centered approach, incorporating case studies, and testing the developed tools in different educational settings, the project aims to enhance teaching methods and materials to support digital and green capabilities in the higher education sector.*

1 Introduction

The "Fourth Industrial Revolution" in manufacturing and production engineering leverages advancements in computer sciences, introducing new solutions at almost every production stage [1], [2]. Key concepts include cybersecurity, cloud computing, knowledge-based engineering, virtual reality, rapid prototyping, big data and artificial intelligence [3], [4] .

In industries such as manufacturing, aerospace, automotive, and energy, sensors are enabling machines and systems to become intelligent—self-aware, predictive, reactive, and social. This intelligence fosters new creativity and capabilities for people, manufacturers, and operators. FabLabs (Fabrication Laboratories), with their industry-oriented focus, serve as innovation hubs where professionals can collaborate, experiment and drive advances in industrial IoT (Internet of Things) technologies [5]. They play a crucial role in bridging the gap between theoretical concepts and practical implementations in the industrial IoT landscape.

The development of customised education and training methods for IoT and FabLab users is essential to fully exploit the potential of the Fourth Industrial Revolution [6]. FabLabs, which are often part of universities or research centres, urgently need IoT knowledge. Early education, especially in secondary schools, is ideal for paving the way for this revolution [7]. Students can handle materials and tools and lay a technological foundation in STEM/STEAM (Science, Technology, Engineering and Mathematics/ Science, Technology, Engineering, Arts and Mathematics) subjects that will influence their future study and career preferences through active and creative engagement with IoT developments [8].

Therefore, our Erasmus+ project called FabLabs [9] is developing training material to support FabLab users and FabLab tutors/teachers, including content for design, programming and manufacturing with a focus on IoT, AI (Artificial Intelligence), Big Data and Blockchain technologies. UL – University of Ljubljana (Slovenia) is the applicant organization, and five other partner organizations are involved, namely: CATIM – Centro de Apoio Tecnologico a Industria Metalomecanic a Associacao (Portugal), T2I – Trasferimento Tecnologico e Innovazione Scarl (Italy), CESGA – Fundacion Publica Gallega Centro Tecnologico de Supercomputa cion de Galicia (Spain), BIBA – Bremer Institut für Produktion und Logistik Hmbh (Germany) and UVIGO – Universidad de Vigo (Spain).

The goal of this paper is to show how important such projects in collaboration with partners and institutions are for progress in education. The target group of this project are in the first-place teachers, university students and high school seniors (in the form of summer school) to get them interested in this topic. FabLabs are a democratic space where anyone can learn and create prototypes using digital fabrication, so companies and economically disadvantaged groups are also a target group. Other priorities in line with the objectives of our project are the promotion of digital and green skills of the higher education sector and the development of STEM/STEAM and higher education, especially the participation of women in STEM.

According to the Global Gender Gap Report 2023, women make up only 29.2% of all STEM workers in 146 countries [10]. M.V. Zubiaur et al. [11] reported, that FabLab are conducive to the integration of women with an interest in STEM fields and increase opportunities in various areas of engineering and related disciplines. The findings highlight aspects that favour the presence of women, supported by the project-based learning model of FabLabs, which does not differentiate between genders and encourages collaboration, experimentation and knowledge sharing, among others.

2 Role of FabLabs in Education

FabLabs are increasingly being integrated into educational environments, from elementary school to universities, emphasizing hands-on learning, creativity and collaboration. Integrating FabLabs into educational institutions will better prepare students for the challenges of the 21st century and foster a generation of innovators and practical problem solvers.

University FabLabs provide access to digital fabrication tools like 3D printers, laser cutters, and CNC machines, supporting research and development in fields like engineering, architecture, and design. They often operate on an open access model, encouraging interdisciplinary collaboration and allowing users to quickly turn ideas into prototypes.

Many universities integrate FabLabs into their academic programs and offer courses or workshops where students learn how to use the equipment and apply digital fabrication techniques. This hands-on experience enhances traditional classroom learning. In addition, FabLabs often engage with the local community by offering events, workshops, and outreach programs. This helps build connections between the university and the surrounding community and promotes STEM/STEAM education. IoT-focused FabLabs, enriched with new types of educational materials and project-based learning, further equip students to succeed in the evolving tech landscape.

3 Survey results of FabLabs - IoT

For the development of new types of educational materials for IoT-oriented FabLabs, a survey was conducted to identify the needs of the potential user groups:

1) university students (with a particular focus on female students, who are highly underrepresented in engineering and technology in the EU)
2) university professors,
3) companies, and
4) secondary school students in their final years before entering higher education.

All four groups mentioned above were also the main target group of this survey. The questionnaire was imaginatively designed by the authors to obtain as much useful and important information as possible. Following results reflect the results and analyses of the answers to the survey in all country partners: University of Ljubljana (Slovenia), BIBA- University of Bremen (Germany), T2i (Italy), CATIM (Portugal), CESGA and University of Vigo (Spain).

In the survey 187 people took part, but only 92 completed it fully. The users were 42.39% female and 57.61% male and between 16 and 65 years old. The survey was divided into three types of profiles: for teachers/tutors, students and technical staff. The survey was completed by 53.5% of teachers/tutors, 25% of students and 21,7% of technical staff. Their teaching/scholar level is shown in Figure 1, with Bachelor’s and Master’s degrees dominating in all profiles.

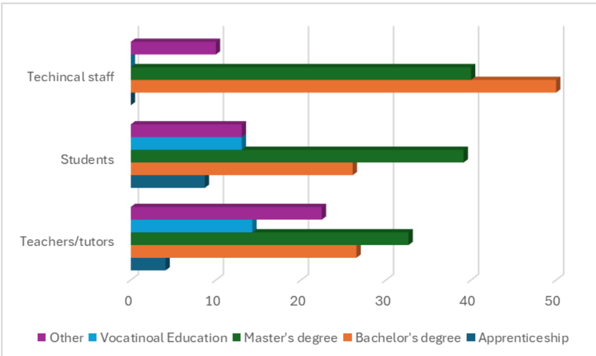

Figure 1. Teaching/scholar level of the participates.

Figure 2 shows, that almost all participants have at least a basic knowledge of digital competence when using ICT in their teaching or support. Advanced knowledge of digital competence is mainly reported by teachers and tutors, while intermediate knowledge is mainly reported by students and technical staff. Participants who reported having experience with eLearning were asked about their preferred eLearning formats. Most participants chose interactive tutorials, instructional videos, and online courses with webinars as their preferred format.

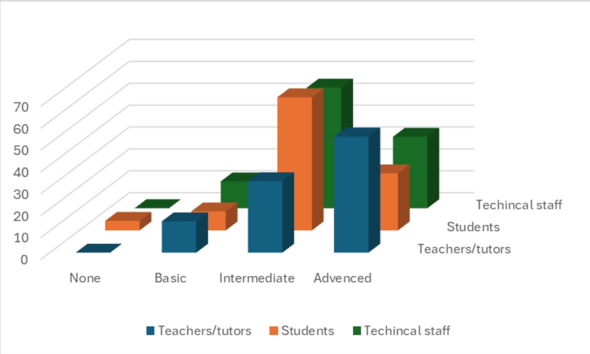

Figure 2. Assessment of the participants' knowledge of their digital competences.

In the survey conducted, participants were also asked to name the technologies and tools that they consider most important for the near future and that should be available in the FabLab. The specific question included a list of technologies/tools and asked participants to indicate the most important ones. As shown in Fig. 3, the technologies most frequently selected by participants were IoT, robotics, general electronics and artificial intelligence/machine learning. These technologies reflect current trends in which connectivity, automation, and intelligence play a fundamental role. In addition, additive manufacturing (3D printing) and CAD/CAE (design and analysis software) were also mentioned by the participants'. These technologies are related to the ability for rapid prototyping and product design, essential aspects of a FabLab. Another technology mentioned by participants was big data, which points to the importance of analysing large amounts of data to gain insights and make informed decisions.

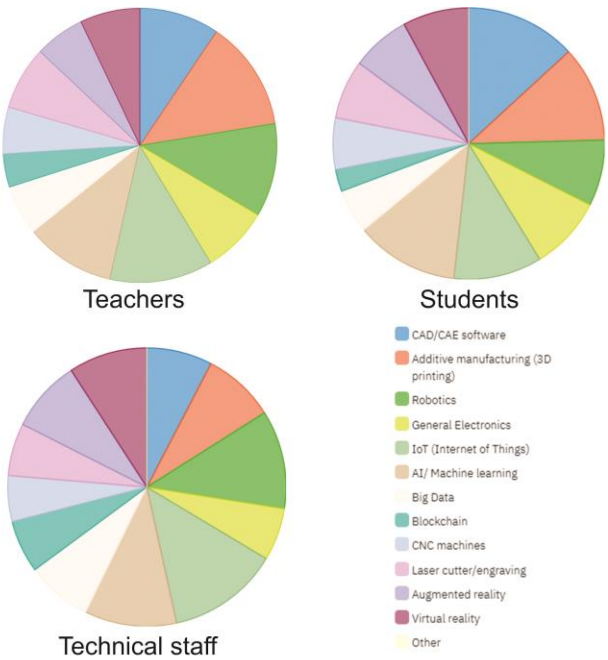

Figure 3. Most important technologies/tools for the near future and to have in FabLab.

In order to determine how important it is to asses prior knowledge before starting the training, participants were also asked whether they thought it was important to assess prior knowledge. Most participants answered this question in the affirmative and emphasized the importance of assessing prior knowledge as shown Fig. 4. When asked about their preferred channels for managing or seeking assistance with technologies, participants selected face-to-face lectures, eLearning, and blended learning (combining eLearning with workshops).

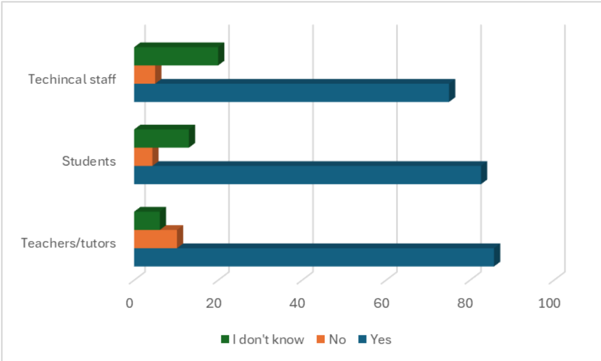

Figure 4. Importance to evaluate the pre-knowledge before training starts.

However, as can be seen in Fig. 5, many of the respondents do not seem to know that there is a FabLab in their school/university/community, indicating a lack of promotion of this important tool for learners, makers and entrepreneurs. Promoting FabLabs involves raising awareness, generating interest and encouraging engagement from students, faculty and staff.

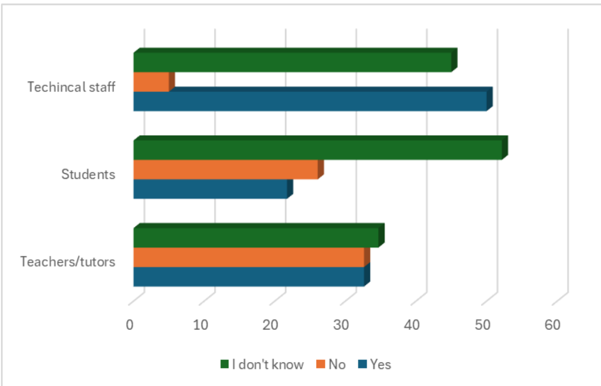

Figure 5. Knowledge of the existence of a FabLabs facility.

4 Development of learning materials and guidelines

The structure of the learning materials was developed taking into consideration the results of the survey and based on the typical FabLab skills. The development of learning materials and guidelines consists of four main topics:

1. Internet of Things (IoT) is a concept which is affecting our lifestyle in a meaningful way, particularly in this period of pandemic when the digital transformation of our society is progressing at an unprecedented speed.
2. The development of the industry grade IoT products is an interdisciplinary project that requires knowledge in computer science, electrical engineering, mechanical engineering, physics and design theory.
3. Learning materials on blockchain technology and its applications for the Internet of Things are being created. Blockchain is a newer concept that uses cryptographic hashes to link blocks of information. In the context of the Internet of Things, blockchain can support embedded systems with distributed services (i.e. smart contracts, distributed databases, etc.) that enable IoT devices to function autonomously and offer and use services from others.
4. Learning materials and guidelines for AI, Bigdata and sensoring: The main objective is to provide a practical reference for these three concepts (AI, bigdata, sensoring) and their inter-relations, applied to IoT projects.

5 Feminist perspective included in Fablabs

Promoting women's participation in STEM/STEAM is essential not only for achieving gender equality but also for fostering innovation, economic growth, and solving global challenges. By ensuring that women have the opportunities and support to thrive in these fields, society as a whole benefits from a more diverse, skilled, and innovative workforce. Diverse teams, including those with gender diversity, bring a wide range of perspectives that lead to more holistic and innovative solutions. This diversity of thought is critical to tackling complex scientific and technological challenges. Products and services developed by diverse teams are more likely to meet the needs of a broader audience. Women's insights can lead to innovations that are more user-friendly and inclusive.

Despite progress, there are still barriers that require further efforts in education, mentoring, policy and cultural change to create an inclusive environment for women in these fields. By incorporating soft skills and a feminist perspective into FabLabs for IoT, we can create more inclusive and equitable spaces where diverse voices are heard, valued, and empowered to contribute to the design, development, and deployment of IoT technologies that benefit all members of society. By providing access to tools, resources, and supportive communities, these initiatives help to break down barriers and empower women to thrive in the rapidly evolving technological landscape.

6 Conclusions

The Erasmus+ FabLabs project aimed to develop learning and teaching strategies, didactic methods, and learning materials to improve the understanding of IoT-related technologies such as Blockchain, AI and Big Data in FabLabs. A survey identified user preferences for interactive tutorials, instructional videos, and blended learning formats (eLearning with workshops).

All materials will be tested in teacher courses, improved based on feedback and included in the final toolkit. The main target group is teachers and students working in FabLabs, although the results are also transferable to other digital fabrication labs and industries. The project also incorporates a feminist perspective to create inclusive FabLabs that challenge gender norms and empower women to contribute.

References

[1] M. Gamal, O. A. Ibrahim, H.F.A. Hamed, S.F.M.Abd-Elnaby: Engineering's Next Leap: How Furth Industrial Revolution is Shaping the Future of the Industry, ERURJ 2024, 3, 2, 970-992.

[2] M. Xu, Jeanne M. David, S.H. Kim: The Fourth Industrial Revolution: Opportunities and Challenges, International Journal of Financial Research 2018, 9,2.

[3] S. K. Jagatheesaperumal, M. Rahouti, K. Ahmad, A. AlFuqaha, M.Guizani: International Journal of Financial Research, IEEE Internet of Things Journal 2022, 9, 15, 12861.

[4] Y.-S. Jeong, J. H. Park: Artificial Intelligence for the Fourth Industrial Revolution, Journal of Information Processing Systems 2018, 14, 6, 1301-1306.

[5] L. Angrisani, P. Arpaia, F. Bonavolonta, N. Moccaldi, R.S. Lo Moriello: A "learning small enterprise" networked with a FabLab: An academic course 4.0 in instrumentation and measurement, Measurement 2020, 150, 107063.

[6] S. Elayyan: The future of education according to the fourth industrial revolution, Journal of Educational Technology and Online Learning, 2021, 23-31.

[7] K. Dressen, S. Schepers: Foregrounding backstage activities for engaging children in a FabLab for STEM education, International Journal of Child-Computer Interaction 2019, 20, 35-42.

[8] S. A. Soomro, H. Casakin, G. V. Georgiev: A Systematic Review on FabLab Environments and Creativity: Implications for Design, Buildings 2022, 12(6), 804.

[9] Erasmus+ Fablabs, https://fabs-erasmus.eu/

[10] Global Gender Gap Report, https://www.weforum.org/publications/global-gender-gap-report-2023/digest/

[11] M. V. Uiboair. P.C. Herrera, V. C. Nuflo: Women in the Fab Lab ecosystem (2008-2021). From Fab Academy to the Fab Lab Research Conferences, Canada 2021.